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Appendix G

Subjective Evaluation Program and Platform

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1 Introduction

The Subjective Evaluation Program was designed to demonstrate that (a) consumers judge the audio quality of iBiquity's FM IBOC system as qualitatively better than currently available FM analog reception, and (b) the FM IBOC system operates with minimal impact to existing FM audio quality. To that end, iBiquity has worked closely with the Advanced Television Technology Center (ATTC) and Dynastat Laboratory to create and execute a comprehensive subjective test program for NRSC evaluation. **Exhibit 1** is a flow chart that shows specific activities within the subjective evaluation program, and the organization responsible for the activity.

This appendix summarizes the methodology used in subjective evaluations, and reviews the process by which sound samples were generated, tested and analyzed. For information concerning specific experimental procedures and methodologies, refer to **Appendix H** – Dynastat Audio Testing Methods and Procedures.

The Subjective Evaluation Program was divided into two areas: (a) field and lab performance testing and (b) field and lab compatibility testing. In order to complete subjective evaluation of all audio material, eleven experiments were conducted at Dynastat. Each experiment lasted approximately 2 ½ hours, including participant training, screening and testing. Table 1 lists these experiments including the material that was tested and their corresponding NRSC test, where applicable.

Table 1: Experiments conducted at Dynastat

Experiment	Material Tested	NRSC Test
1	Lab compatibility	F, J
2	Lab compatibility	F, G, J
3	Lab compatibility	F, G, J
4	Lab SCA compatibility	F/SC
5	Field Performance – Blend (5b) Field Compatibility (5a)	B C
6	Field Performance - Multipath	B
7	MOS Interpretation (7a) Field Performance – Dual 2nds (7b)	n/a B
8	Field Performance	B
9	Durability (Ticker and ACR)	n/a
10	Field SCA compatibility	C.2
11	Lab Performance	B,C,D,E

2 Sound Sample Generation

2.1 Source material and Pre-processor settings

Original source material used for all FM subjective testing was proposed by an ad hoc Test Audio Selection Group that reported to the NRSC's Test Procedures Working Group. Thirty-three sound samples were selected for impairment testing, and a sub-set of 16 samples were selected for clean-channel testing. Sound samples were grouped together in equivalent "families" (i.e., samples exhibiting the same characteristics) so that they could be used interchangeably in subjective experiments. Because certain experiments required participants to listen to 200+ sound samples, it was felt that severe listener fatigue would occur if the same sound samples were repeated over and over. Therefore, where appropriate, equivalent sound samples were used to minimize the effects of listener fatigue. However, when substituting equivalent sound samples, all care was taken to use the same cut within a specific condition. See **Appendix I** – Results Tables for the specific samples used in each condition.

For all analog recordings, pre-processor settings were established by Frank Foti, of Omnia Corporation. For all digital recordings, pre-processor settings were established by Greg Oganowski, of Orban Corporation. **Exhibit 2** is a complete listing of sound samples and their associated pre-processing settings. (See **Exhibit 3** for a detailed description of the selection process and original list of sound samples submitted to the NRSC.)

2.2 Lab Test Audio Samples

All audio samples were generated at ATTC in accordance with the NRSC test program. Sound samples were recorded, edited, and leveled at ATTC and subsequently sent to Dynastat for evaluation. With the exception of "sample failures", editing and leveling of all samples were performed identically for lab and field testing. (See **Exhibit 4** for editing and leveling guidelines used for both lab and field recordings.) Sample failures were defined as those audio segments in which (a) noise created by the interferer was stronger than the signal, so that the signal was no longer audible or editable with editing software, and (b) the interfering signal was stronger than the primary signal such that the interferer was heard clearly, but the signal of interest was no longer audible or editable. Sample failures were archived, but were not sent to Dynastat for testing.

Additionally, in two conditions (Compatibility test: 1st adjacent interference with urban slow multipath, and Performance test: 1st adjacent interference with urban slow multipath) it was necessary for a 3-person panel to select the samples included for testing. **Exhibit 5** describes the process by which samples were selected. All standard editing and leveling procedures were followed for these samples.

2.3 Field Test Audio Samples

Audio was recorded in the field onto DA-98 tapes, selected and processed by iBiquity for submission to Dynastat. Field data corresponding to field audio was collected using iBiquity's custom data acquisition software, TakeATest. See **Exhibit 6** for a complete description of field test audio selection.

2.3.1 Selection Process

In order to select the precise locations in which signals of interest existed, iBiquity software initially analyzed raw field test data by calculating powers and desired-to-undesired ratios for all audio. Next, using a query tool, audio segments were selected based on signal strength, D/U ratios and interference conditions. A variety of conditions were identified for inclusion into testing. These included:

- 1^{st} and 2^{nd} adjacent Interference (instances of single 1^{st} and 2^{nd} adjacent interference)
- Dual interference (instances of dual 2^{nd} adjacent interferences)
- Multipath
- Blend samples

1^{st} Adjacent Interference Search Criteria included all instances of single and dual 1^{st} adjacent interference within the digital coverage area where D/U $\leq$23dB and the received desired signal strength, D $\geq$ -80dBM (approximately 36 dBu at 2 m above ground level). 2^{nd} Adjacent interference search criteria included all instances of single and dual 2^{nd} adjacent interference within the digital coverage area where D/U < 0dB and the received desired signal strength D $\geq$ -80dBM. Dual interference search criteria included all instances where both 2^{nd} adjacent D/U < 0dB and the received desired signal strength D $\geq$ -80dBm.

For Multipath samples, iBiquity concentrated on test data from KLLC and KWNR, stations from two cities noted for pervasive multipath propagation conditions. Criteria for choosing multipath audio samples included the following:

(a) The analog recordings contained multipath artifacts, such as pops, fades, swooshing over the range of light to severe.
(b) The IBOC radio was in digital mode for the duration of the audio sample.
(c) The audio contained programmatic material acceptable for subjective evaluation.

Point-of-Blend samples were a representative set of field audio cuts during transition from analog to digital and/or digital to analog receiving modes. iBiquity chose these samples across combinations of program material, receiving conditions and blend sequences. Audio samples were taken from KLLC, WD2XAB, WETA, WHFS, and WPOC. For each station, potential sample stretches where blending occurred were identified, and audio was recorded. Both location within the service area and blend transition patterns were taken into consideration.

Field audio was converted from DA98 to wave files for the purpose of editing. For performance tests, audio was recorded simultaneously through the IBOC, Delphi and Pioneer receivers. 15-second segments were selected based on time-code records. All audio streams were edited exactly at the same start-and stop-point, so that direct comparisons could be made within conditions. For compatibility tests, audio was recorded with IBOC DAB being turned on and off at 30-second intervals. For each location, test samples were created by choosing 2 comparable 15-second segments (one with IBOC off, and one with IBOC on). **Exhibit 7** describes the procedures for processing compatibility field test samples, giving specific examples from one compatibility experiment.

3 Participant Testing

All subjective evaluations were conducted at Dynastat. Each experiment included 40 listeners, stratified both for listener gender and age. All participants were trained prior to testing and screened twice. Participants were given a pre-screening test designed to eliminate those listeners who could not easily hear impairments. Second, a post-hoc analysis was conducted on all listeners to determine the reliability of results for each listener. These screening procedures are outlined in **Appendix H.** Although listeners were drawn from the general public, it is important to note that they were both trained to detect impairments and capable of discriminating impaired audio from unimpaired reference material. iBiquity believes that by training and screening participants in this fashion, their resulting data portrays an extremely conservative picture of consumer satisfaction and acceptability.

Experiments were conducted in acoustically designed sound rooms that contained minimal environmental noise. Approximately 200 sound samples were presented to participants during each experiment. Participants listened to all samples over high-quality Sennheiser headphones, and recorded their responses directly to a workstation. Presentation of audio samples over headphones was chosen in order to make experiments as reliable and repeatable as possible. However, it is probable that presenting audio over high-quality headphones affected listeners' judgments conservatively. That is, listeners on headphones were undoubtedly more critical of audio than if they had been presented with the audio over auto speakers.

Except for the Durability study (Ticker), the methodology for all experiments was the Absolute Category Rating Method (ACRM). In ACRM participants judge sound samples on an individual basis, using an implicit reference to judge the quality of the sound sample. Within a particular ACR experiment participants generally hear a variety of sound-samples that may differ on several dimensions. Their mission is to give a statement of "overall quality", taking into consideration the variety of audio elements that may be present. (See **Appendix H** for more detailed information concerning the ACRM.)

4 Analysis of Data

At the conclusion of each experiment, Dynastat delivered results in the form of Excel worksheets to iBiquity. One worksheet included the listeners that were kept in the final data set. The other worksheet contained the raw response data for those listeners. Analysis of data was performed at iBiquity, audited and certified by Dynastat, and included in this report as a series of tables. Data was aggregated from all 11 experiments, and placed into 4 excel workbooks: NRSC Field Compatibility; NRSC Lab Compatibility; NRSC Field Performance; and NRSC Field Compatibility. All mean opinion scores are presented, as well as the confidence intervals for each score. The format of these tables was designed by iBiquity and accepted by the NRSC Evaluation Working Group. Criteria used to establish tables were as follows:

- Data from individual subjective experiments were combined in order to create tables that correspond to the NRSC test program.
- All participants' responses were aggregated;
- Individual audio samples (i.e., Carmen, Santana, etc.) were collapsed into their corresponding genres (Classical, Rock, and Speech);
- Responses from genres were combined into a column headed "Total"
- All conditions were preserved
- Receivers were presented individually.
- Standard deviations (confidence intervals) were calculated for each cell
- Failed samples (defined as sound samples not sent to Dynastat for rating) were not aggregated into the MOS, but were noted in the particular cell as a "failure"
- Anchor information for individual subjective experiments was not included

Exhibit 1

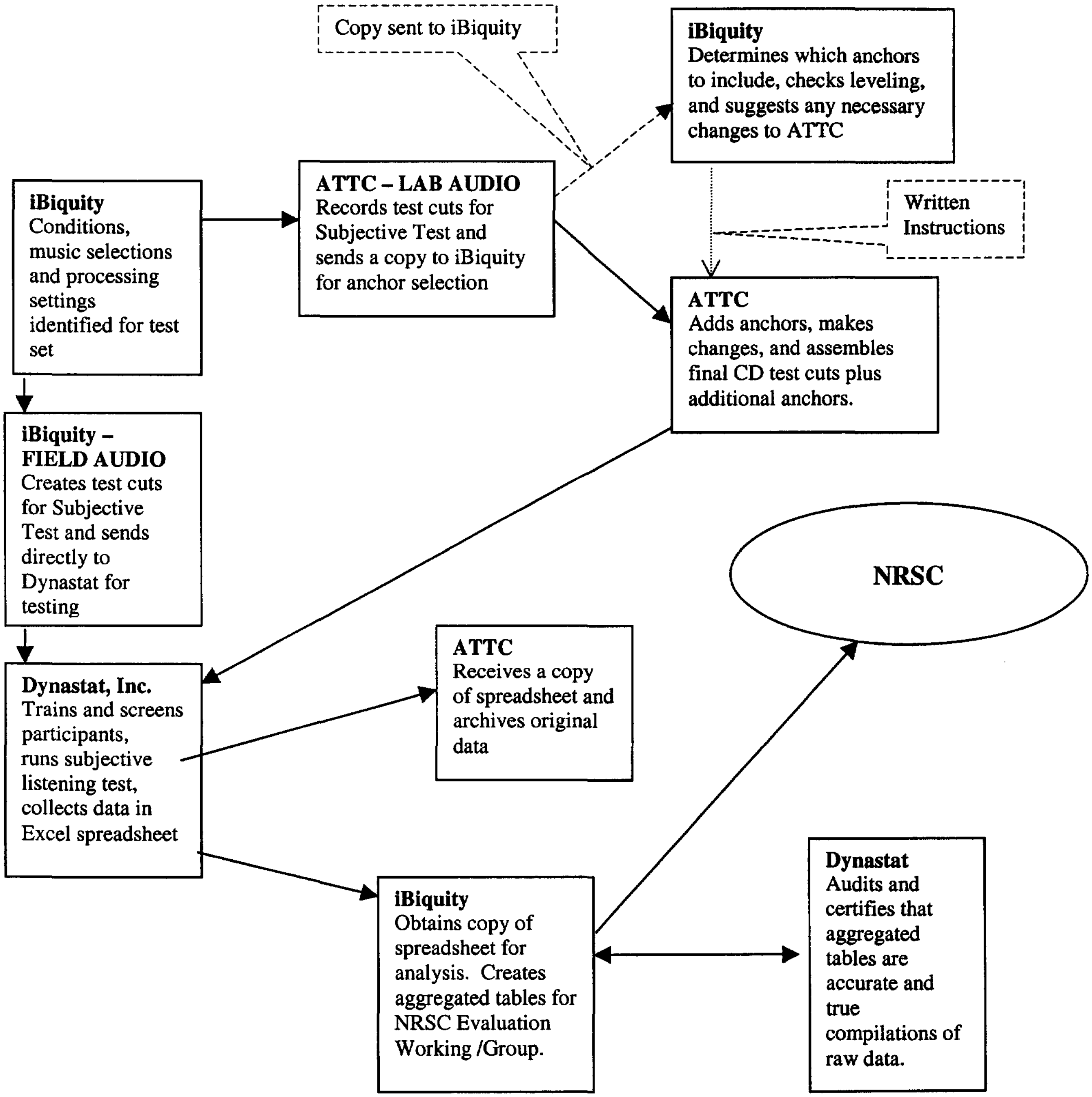
Copy sent to iBiquity
iBiquity
Determines which anchors to include, checks leveling, and suggests any necessary changes to ATTC
iBiquity
Conditions, music selections and processing settings identified for test set
ATTC – LAB AUDIO
Records test cuts for Subjective Test and sends a copy to iBiquity for anchor selection
Written Instructions
ATTC
Adds anchors, makes changes, and assembles final CD test cuts plus additional anchors.
iBiquity – FIELD AUDIO
Creates test cuts for Subjective Test and sends directly to Dynastat for testing
NRSC
ATTC
Receives a copy of spreadsheet and archives original data
Dynastat, Inc.
Trains and screens participants, runs subjective listening test, collects data in Excel spreadsheet
Dynastat
Audits and certifies that aggregated tables are accurate and true compilations of raw data.
iBiquity
Obtains copy of spreadsheet for analysis. Creates aggregated tables for NRSC Evaluation Working /Group.

Exhibit 2

NRSC AUDIO SUBMISSION LISTING

ARTIST	ALBUM TITLE	SONG TITLE	ASIN NUMBER	TIME	Analog Pre-processor settings	Digital Pre-processor settings
Bach	Brandenburg Concerto #5, D Major	Allegro	B000003CZT	9:02-9:19.39	Light	Transparent
Toni Basil	VH1 More of the Big 80's	Mickey	B00000342B	1:07-1:30.283	Hard	Contemp 1
Jeff Beck	Who Else	Mama Said	B00000I924	2:57-3:20.09	Jacked	Not Used
Bizet	Carmen		B0000007DT	0:48-1:05.93	Light	Transparent
Enya	Shepherd Moons	Angeles	B000002LRT	1:54-2:14	Light	Transparent
Eric Clapton	Best of Eric Clapton	Change the World	B00001U03Q	0:50-1:11	Medium	Transparent
Paula Cole	Harbinger	Happy Home	B000002N2I	0:40-0:59.912	Medium	Contemp 2
Crowded House	Woodface	Weather With You	B000006MVE	0:18-0:39.515	Medium	Contemp 1
Crosby, Stills, Nash, & Young	Looking Forward	Sanibel	B000021XQS	2:12-2:35.53	Medium	Contemp 2
Debussy	String Quartet in g minor	Anime et tres decide	B000001GNA	1:43-2:04.25	Light	Transparent
Earth, Wind and Fire	Greatest Hits	Let's Groove	B00000FC5H	2:26-2:50.18	Hard	Contemp 1
Donald Fagen	The Nightfly	I.G.Y	B000002KXV	2:25-2:51.347	Medium	Contemp 2
Fleetwood Mac	Tango in the Night	Big Love	B000002L9Y	0:23-0:44.163	Medium	Contemp 2
Glockenspiel	SQAM Disc		N/A	single cut	Light	Transparent
Amy Grant	Heart in Motion	Baby, Baby	B000002GJB	0:19-0:44.043	Hard	Contemp 1
Handel	Messiah	Hallelujah	B000003CY	0:07-0:31.594	Light	Transparent
Jaques Ibert	Summertime Music for Oboe	Entr'acte	B000000A9T	0:33-0:56.878	Light	Transparent
Metallica	Metallica	The Unforgiven	B000005RUG	3:37-3:59.824	Jacked	Not Used
Medewski, Martin and Wood	Shack Man	Hermeto's Daydream	B000003220	1:15-1:35-346	Medium	Light
Moulton Labs	Critical Listening Excerpts CD	Kyoko Saito	N/A	Cut 3	Light	Transparent
Moulton Labs	Bang & Olufsen Test Sequence	Robert Cray	N/A	10:04-10:28.3	Medium	Contemp 1
Saba	Persian Classical Music	The Yellow Sparrow	Foreign recording	N/A	Light	Transparent
Prince	The Hits 1	Diamonds and Pearls	B000002MN5	2:12-2:35.212	Hard	Contemp 1
REO Speedwagon	Hi Fidelity	Keep on Loving You	B0000025KF	2:13-2:33.568	Hard	Contemp 1
Carlos Santana	Supernatural	Smooth	B00000J7J4	3:27-3:50	Hard	Contemp 2
Paul Simon	Rhythm of the Saints	Can't Run but	B000002LKF	0:21-0:46.018	Medium	Light
Lisa Stansfield	Lisa Stansfield	The Real Thing	B000002VNO	3:09-3:31.236	Hard	Contemp 1
Stravinski (Bernstein conducts)	Firebird	Track 5	B000001GNV	0:23-0:44.163	Light	Transparent
Tchaikovsky Classical Thunder	1812 Overture	Track 17		0:34.1-0:50.3	Light	Transparent
Randy Travis	A Man Ain't Made of Stone	A Heartache In the Works	B00001QGNB	0:54-1:16.366	Medium	Light
Trumpet	SQAM Disc		N/A	single cut	Light	Transparent
Suzanne Vega	Nine Objects of Desire	Caramel	B000002G60	0:31-0:48.041	Medium	Contemp 2
English Woman	SQAM Disc		N/A	single cut	Light	Transparent
Tom Brokaw	The Greatest Generation		0375405666	0:00-0:17.49	Light	Light
English Male	SQAM Disc		N/A	single cut	Light	Transparent

Exhibit 3

To: **Andy Laird, Chairman of Test Procedures Working Group**

From: **Ellyn G. Sheffield**

Date: **November 17, 2000**

Re: **Recommended Sound Samples from the Test Audio Selection Ad-Hoc Group**

Test Audio Selection Ad-Hoc Group
Tim J. Carroll
Frank Foti
David Maxson
Ellyn Sheffield
Emil Torick
Greg Nease, Moderator

This memorandum describes the process of selecting sound cuts for NRSC IBOC-DAB testing. **Attachment 1** is the recommended list of sound samples, including general descriptions of the source material and how they were ranked.

Sound Sample Pool

Sound samples were submitted for evaluation by Ellyn Sheffield on behalf of Ibiquity Digital Corp., Tim Carroll on behalf of Dolby Laboratories, Inc., and Ralph Justice. Forty-eight (48) musical samples and 2 speech samples were submitted, reviewed and evaluated (**Attachment 2** is a full listing of submissions). At the request of iBiquity during the meeting, Dolby recommended 2 additional sources to locate appropriate speech samples. These samples are not included in this evaluation, but will be transmitted to the NRSC under separate cover.

Evaluating Sound Samples

Evaluations were made as follows:

1. Samples were processed through PAC at 64 kbits/sec. In the beginning of the listening session, all samples were played once to afford committee members the opportunity to hear all samples they would be judging.
2. Originally it was agreed that samples would be rated on a 3-point scale (Low, Medium or High) depending on how rigorously they stressed the digital coder. After listening to several selections, it became clear that this scale did not afford enough resolution and Low-Medium, and Medium-High were added. Therefore, samples were actually rated on a 5-point scale (1 = Low; 2 = Medium/Low; 3 = Medium; 4 = Medium/High; 5 = High).
3. Each sound sample was played through PAC64 on a real-time system, listened to over Sennheiser HD-600 headphones. If impairments were obvious, the selection was simply rated. However, if listeners were having difficulty deciding upon a rating the source material was played in order to compare the encoded version to the original.
4. Ratings were individually expressed, and consensus was reached on a final rating for each sound sample. Then, each listener described the specific impairments they heard. These comments were recorded by Greg Nease.
5. In order to ensure that some group choices also would also stress analog transmissions, select sound samples were played through an FM-analog transmission chain (including an Omnia FM audio processor/stereo generator, Rohde and Schwarz laboratory signal generator, coaxial cable, high-end Marantz receiver and Rotel audio pre-amplifier) over high-end speakers. Selections stressing analog are highlighted with an * in Attachment 1.

Final Sound Sample List Selection (Clean-channel Tests)

Sound samples were chosen based on the following criteria:

a. Samples needed to be challenging to digital processing (a minimum ranking of 3), and include specific elements that would stress digital transmission.
b. A reasonable percentage of sound samples needed to be challenging to FM analog processing (these could also be challenging to digital processing),
c. The total group of selections needed to represent a wide range of existing musical styles.

Priority was given to musical samples that were very challenging to both digital and analog processing, and that were representative of normal broadcasting material. Two "critical" samples were also included to highlight specific musical elements (a muted trumpet and the glockenspiel).

Sixteen musical samples and two speech samples[1] were selected.

Selecting Final Sound Sample "Families" (Impaired Laboratory Tests)

Sound samples were grouped together in equivalent "families" (i.e., samples exhibiting the same characteristics). The group consisted of the 16 samples chosen for clean-channel testing and additional samples that were excluded from the final clean-channel list. This list was created solely for compatibility and performance testing in impaired conditions (see **Attachment 3**). Because certain impairment tests require participants to listen to 200+ sound samples, it was felt that severe listener fatigue would occur if the same 2-3 sound samples were repeated 60-100 times. Therefore, where appropriate, equivalent sound samples can be used to minimize the effects of presenting the same stimuli repeatedly.

[1] Two additional speech samples will be selected by iBiquity, and distributed to listeners for approval.

Attachment 1

Sound Sample Selections Recommended to the NRSC

Sound Sample	**Description**	**Degree of Challenge for Digital System**	**Digital Impairment(s) in 64 kb PAC**
Music			
Bach, Brandenburg Concerto (Harpsichord)	Classical Solo Harpsichord and Orchestra	4	Phase distortion, transient distortion (strings), watery
Bizet, Carmen	Orchestra featuring castanets, bells and other percussive instruments	5	Transient distortion, pre-echo distortion (castanets, harp)
Handel Messiah	Choral with Orchestra	5	Overall fidelity; loss of image integrity
1812 Overture*	Orchestra, featuring cannons	3	Percussive transient distortion (cannon)
Kyoko Saito	Female Opera with piano	3	High-frequency distortion (warbling); loss of image integrity
Medewski, Medin and Wood	Jazz Instrumental	5	Smearing; wavering (piano); thin
Trumpet*	Solo trumpet arpeggio (muted)	5	Loss of realism
Glockenspiel*	Critical sample, 4 tones	5	Intermodulation; fuzziness; loss of decay; warbly
Turkish Folk Music	Alternative featuring unusual percussion	4	Loss of high frequencies; loss of realism; loss of detail
Paul Simon, *Can't Run But*	Alternative featuring unusual percussion	4	Loss of definition in percussion; vocal distortion
Amy Grant*, *Baby Baby*	Female Vocal Rock	5	Intermodulation; fuzziness; watery
Earth, Wind and Fire*, *Let's Groove*	Rock Instrumental/Choral	5	Dynamic phase distortion; Loss of definition; Watery; Buzzy
Enya	New Age, featuring bass clarinet	4	Loss of realism; Wavering; warbling

Sound Sample	**Description**	**Degree of Challenge for Digital System**	**Digital Impairment(s) in 64 kb PAC**
Eric Clapton, *Change the World*	Male Vocal Rock	4	Vocal roughness; sibilance; background coloration
Randy Travis, *A Little Bitty Crack in her Heart*	Male Vocal Country	5	Vocal distortion; Harsh; Phase distortion; Modulated background
Speech			
English Woman*	Female	5	Vocal distortion; doubling
Tom Brokaw*	Male	5	Vocal distortion; doubling

* Stresses analog processing substantially

Attachment 2

Complete Listing of Submissions

	Artist, Album, Sound Track	Description	Digital Rating
1	Castinets (Sqam disc)	Critical Sample	4
2	Fountain Music (from NRSC disc)	Critical Sample	Eliminated without rating (artificial)
3	Tchaikovsky, *1812 Overture*	Classical Instrumental	3
4	Bach, Brandenburg *Concerto*, Presto	Classical Instrumental	5
5	Jeff Beck, *Who Else*, What Mama Said	Rock Instrumental	2
6	Tom Brokaw (The Greatest Generation)	Speech Male vocal	5
7	Bizet's *Carmen*	Classical Instrumental	5
8	Eric Clapton, *Best of Eric Clapton*, Change the World	Rock Male Vocals	4
9	Paula Cole, *Harbinger*, Happy Home	Rock Female Vocal	4
10	Copeland, Rodeo	Classical Instrumental	1
11	Moulton Labs, *Critical Listening Excerpts* CD, (*Bang & Olufsen Test Sequence,* Robert Cray	Blues/Jazz Male	3
12	Crowded House, *Woodface*, Weather with You	Rock Male vocal	4
13	Crosby, Stills, Nash & Young, *Looking Forward*, Sanibel	Rock Male vocals	5
14	Debussy Quartet	Classical Instrumental	3
15	Earth, Wind & Fire, *Greatest Hits*, Let's Groove	Rock Male vocal	5
16	Donald Fagen, The Nightfly, I.G.Y	Rock Male vocal	4
17	Stravinski, FireBird	Classical Instrumental	3
18	Fleetwood Mac, *Tango in the Night*, Big Love	Rock Mixed vocals	3
19	Glockenspiel (Sqam disc)	Critical Sample	5
20	Amy Grant, *Heart In Motion*: Baby, Baby	Rock Female vocal	5

	Artist, Album, Sound Track	Description	Digital Rating
21	*Critical Listening Excerpts (Bang & Olufsen Test Sequence),* Britten's Young Person's Guide to the Orchestra	Classical Instrumental	Eliminated without rating (poor recording)
22	Handel, *Messiah*, Hallelujah	Classical Choral	5
23	Jacques Ibert, *Summertime Music for Oboe and Guitar*, Entr'acte	Classical Instrumental	3
24	Metallica, The Unforgiven	Rock Instrumental	2
25	Medewski, Medin and Wood, Cut 2	Jazz Instrumental	5
26	Pink Floyd, *Pyramid*, Eclipse	Rock Instrumental	Eliminated without rating (redundant)
27	Prince, *The Hits 1*: Diamonds and Pearls	Rock Male vocal	5
28	REO Speedwagon, *Hi Infidelity*, Keep On Loving You	Rock Male vocal	3
29	Moulton Labs, *Critical Listening Excerpts* CD, cut 3 *(Kyoko Saito)*	Classical Female	3
30	Carlos Santana, *Supernatural*, Smooth	Rock Male vocal	4
31	Shania Twain, *Come On Over*, That Don't Impress Me Much	Rock Female vocal	Eliminated without rating (redundant)
32	Paul Simon, *Rhythm of the Saints,* Can't run but	Rock/Pop Instrumental	4
33	Lisa Stansfield, *Lisa Stansfield*, The Real Thing	Rock Female vocal	1
34	Toni Basil, *VH1 More Of The Big '80s*: Mickey	Rock Female vocal	1
35	Randy Travis, *A Man Ain't Made of Stone*, A little bitty crack in her heart	Country Male vocals	5
36	Suzanne Vega, *Nine Objects of Desire*, Caramel	Rock Female vocal	3
37	Turkish Folk Music	Folk Instrumental	4
38	English Woman speech (Sqam disc)	Female vocal	5
39	Bass Clarinet Arpeggio (Sqam disc)	Single Instrument	5
40	Muted Trumpet (Pictures at an Exhibition)	Single Instrument	5
41	Suzanne Vega with Breaking Glass, Tom's Diner	Female vocal	Eliminated without rating (artificial)
42	Rain and Clarinet (AT&T creation)	Instrumental with sound effects	Eliminated without rating (artificial)

	Artist, Album, Sound Track	Description	Digital Rating
43	Dire Straits	Intro – Instrumental	1
44	Pearl Jam, Daughter	Rock vocals	1
45	Harpsichord arpeggio	Single Instrument	4
46	Enya, Shepard Moons	New Age Instrumental	4
47	The Sundays, I can't wait	Instrumental	3
48	Liszt	Classical Instrumental	Eliminated (poor recording)
49	Tchaikovsky, Nutcracker Suite	Classical Instrumental	Eliminated without rating (redundant)
50	Rolling Triangle	Single instrument	5

Attachment 3

Families of Sound Samples

Family	Sound Samples
Classical Orchestral	Bach Brandenburg Bizet Carmen Handel Messiah Tchaikovsky 1812 Stravinski Firebird
Lightly Processed Mix	Ibert, Oboe and Guitar Debussy Quartet Kyoko Saito Paul Simon Turkish Folk Music Enya Medewski, Medin, and Wood
Female Vocals (Rock/Pop)	Suzanne Vega Paula Cole Amy Grant* Lisa Stansfield Toni Basil
Male Vocals (Rock/Pop)	Donald Fagen Robert Cray Randy Travis
Pop – instrumental/choral	Earth Wind and Fire Crosby, Stills, Nash and Young Eric Clapton Crowded House Prince Santana Fleetwood Mac REO Speedwagon
Dense Rock	Jeff Beck Metallica
Single Instrument	Trumpet Glockenspiel

*To be used for undesired analog modulation

Exhibit 4

Procedure for Editing and Leveling Sound Samples

1. Editing Sound Samples

When editing a sound sample, the goal is to create an envelope at the beginning and end of the wave file that contains no noise preceding or following the desired music or speech sample. Elimination of noise at the beginning and end of all sound samples is crucial because any noise that is present can serve as a cue that can be used to identify samples during testing.

2. Procedure for Editing Sound Samples

The wave file to be edited is first opened in Cool Edit Pro. The beginning of the waveform is magnified so that it is possible to distinguish between the desired sample and any noise or silence preceding it. All noise or silence preceding the desired sample is deleted from the wave file. Next, the end of the waveform is magnified so that it is possible to distinguish between the desired sample and any noise or silence following it. Any noise or silence following the desired sample is then deleted. Once this has been done, it is necessary to listen to both the beginning and end of the wave file to ensure that all of the noise and silence surrounding the desired sample has been removed and to ensure that none of the desired sample was cut off by the editing that was done. If all of the noise has been removed and none of the desired sample was cut off, then the wave file is saved and editing is completed. If the wave file does not meet these requirements, the changes are undone and the editing process is repeated.

3. Leveling Sound Samples

In subjective testing, it is essential to ensure that all sound samples are level because any leveling differences that may exist could potentially serve as a cue to identify samples during testing. As a rule, music and speech samples are considered "level" when they sound equal in volume, as determined by a subjective listener. In other words, when two leveled samples are played back-to-back, the listener should not feel the need to adjust the volume from one sample to the next.

It is important when leveling sound samples to always level to the signal rather than to the noise. If samples are leveled to the noise, any noise that may be included in the signal (for instance, noise created by IBOC) could potentially be hidden. Consider the case where two samples were being leveled, one that has IBOC On and is noisier and another that has IBOC Off and is less noisy. If one were to level to the noise, the IBOC-On signal would be de-amplified (since that sample is noisier) and, in doing so, the signal would also be de-amplified. This may cause the signal to sound less noisy and hide the effects of IBOC. In contrast, by leveling to the signal, this problem is eliminated.

When leveling, it is also essential to never amplify sound samples. Amplifying samples results in amplification of any audio impairments that may exist in the sound sample, regardless of whether the sample has IBOC On or Off. The overall sound quality of both IBOC Off and IBOC On samples will be more favorable when impairments are not amplified. Thus, samples should always be de-amplified so that they are level with the softest sound sample.

4. Procedure for Leveling Sound Samples

When leveling a group of samples, a subjective listener first listens to each sample to determine which sample is the softest. All other samples will be de-amplified to match the level of the softest sample.

Once the softest sample is identified, the listener listens to the level of the other samples again. Samples will generally divide into similar groupings, based on the pre-processor settings used during the recording process. These groupings are referred to as "bands." The loudest samples are put into the highest band, the softer samples into the softer bands, and the softest samples into the softest band. As many bands as are needed are created. Samples within each band should be approximately the same level.

For each band, the listener listens to the samples and makes sure they are level with each other. If they are not level, the louder samples in the band are de-amplified so they are level with the softer samples in the band.

Once the samples within each band are level, the listener proceeds to level across bands, starting with the loudest band. The loudest band is de-amplified so it is level with the softest band. Then, the second-loudest band is de-amplified so it is level with the softest band (Note: The decrease in decibel level necessary to achieve this will be less than the decrease in decibel level necessary to de-amplify the loudest band to the level of the softest band). The remaining bands are de-amplified (from loudest to softest) to the level of the softest band.

Finally, the listener should listen to all samples to ensure they are all the same level. If an individual sample is louder than the rest of the samples, it is de-amplified so it is level with the others. If an individual samples is softer than the rest of the samples, any de-amplification to this sample is undone and it is de-amplified again so that it is level with the other samples.

Exhibit 5: Multipath audio sample selection

The NRSC Laboratory multipath scenarios were designed to simulate vehicular motion at various speeds. Three of the scenarios represent typical driving speeds (Urban Fast, Terrain Obstructed, Rural Fast). The fourth scenario represents very slow vehicular or pedestrian traffic (Urban Slow). This slow vehicular or pedestrian motion results in multipath scenarios where the instantaneous envelope power also changes at a slow rate. Consequently, in order to adequately test "Urban Slow" multipath conditions in the laboratory, one must wait a sufficient amount of time for several null events to be generated by the multipath simulator. (For the other three multipath scenarios, many nulls will occur in a short amount of time, so this "waiting period" requirement is significantly less.)

Because each audio sample used in the Subjective Test Program was approximately 15 seconds or less, often they were too short for the longer "waiting period" required by the Urban Slow multipath simulation. Thus, it was possible for no multipath impairment to occur in a 15-second time period. Obviously, if the sample occurred in multipath-free conditions, this would not fulfill the spirit of the test for that condition.

In order to find a solution to this problem, 15-second audio cuts were looped repeatedly over a 90 second interval and subjected to Urban Slow multipath for a total of 90 seconds. This time period allowed several multipath null events to occur in Urban Slow conditions.

After this 90-second recording was made, a panel of three voted on which of the 15 second loops sounded most representative of the interference scenario. The panel consisted of Ellyn Sheffield, iBiquity, Sean Wallace, ATTC, and Tom Keller, CEA. Panelists listened to all cases, one-by-one, and voted individually on which case sounded the most representative. All decisions were unanimously agreed upon after brief discussion.

Exhibit 6 – Audio Sample Selection: Field Test Data Analysis Procedures

This document describes the procedures followed to select audio samples from field test recordings. For the purpose of recording the performance of its digital receivers in the field, iBiquity developed a custom data acquisition system. This system includes a GPS receiver, spectrum analyzer, video camera and SMPTE timecode capture module. A personal computer running iBiquity's field test data acquisition software, known as *TakeATest*, controls and coordinates the data capture and storage from the digital radio and test equipment. The fundamental data produced by *TakeATest* are:

- GPS location and time (latitude/longitude coordinates plus GMT seconds in the day)
- Spectral plots of the FM band within several adjacent channels of the IBOC test transmission
- JPEG still shots of the environment around the test van
- SMPTE timecode data from the digital audio recording system
- Telemetry data from the digital receiver
- PC time stamp and test operator hotkey data

For analyzing data iBiquity also developed a set of post-processing software tools that accept input from *TakeATest* files. The first of these, *DataView*, is a PC application that provides VCR-like playback of drive test data, showing captured spectrum, route tracing over a map, SMPTE time code, camera images and radio performance parameters. *DataView* also provides utilities for mathematical processing of the raw field test data. These operate on portions of the spectral data to calculate the powers and desired-to-undesired (D/U) ratios for signals of interest. *DataView* was used for manual data analysis.

DataLoader, iBiquity's primary database builder and query tool, consists of several component modules including:

- A conversion engine for processing and loading *TakeATest* files into the field test relational database
- A report generator for conditional searching of the field test database
- Export modules to extract and format specified field information from the database and export this information to files compatible with other applications, i.e., MS Excel and Delorme Street Atlas

Figure 1 is a screen shot of the *DataLoader*'s Plot & File Generator graphical user interface.

Exhibit 7

To: Andy Laird, Chairman of Test Procedures Working Group

From: Jennifer L. Dail and Ellyn G. Sheffield

Date: May 14, 2001

Re: Selection of Field Test Samples

This memorandum describes the procedure for selecting field test samples for NRSC testing.

I. Field Recordings: Field samples were converted from DA98s to wave files for editing. Each file consisted of multiple 3-minute (or longer) segments, with IBOC DAB being turned on and off at 30-second intervals within a particular segment. All transmissions were recorded simultaneously through the Delphi, Technics, Sony, and Pioneer radios. For six locations, the DAB was turned on and off for the host radio station. For nine locations, the DAB was turned on and off for the first adjacent radio station. See **Table 1** for details about the field recordings.

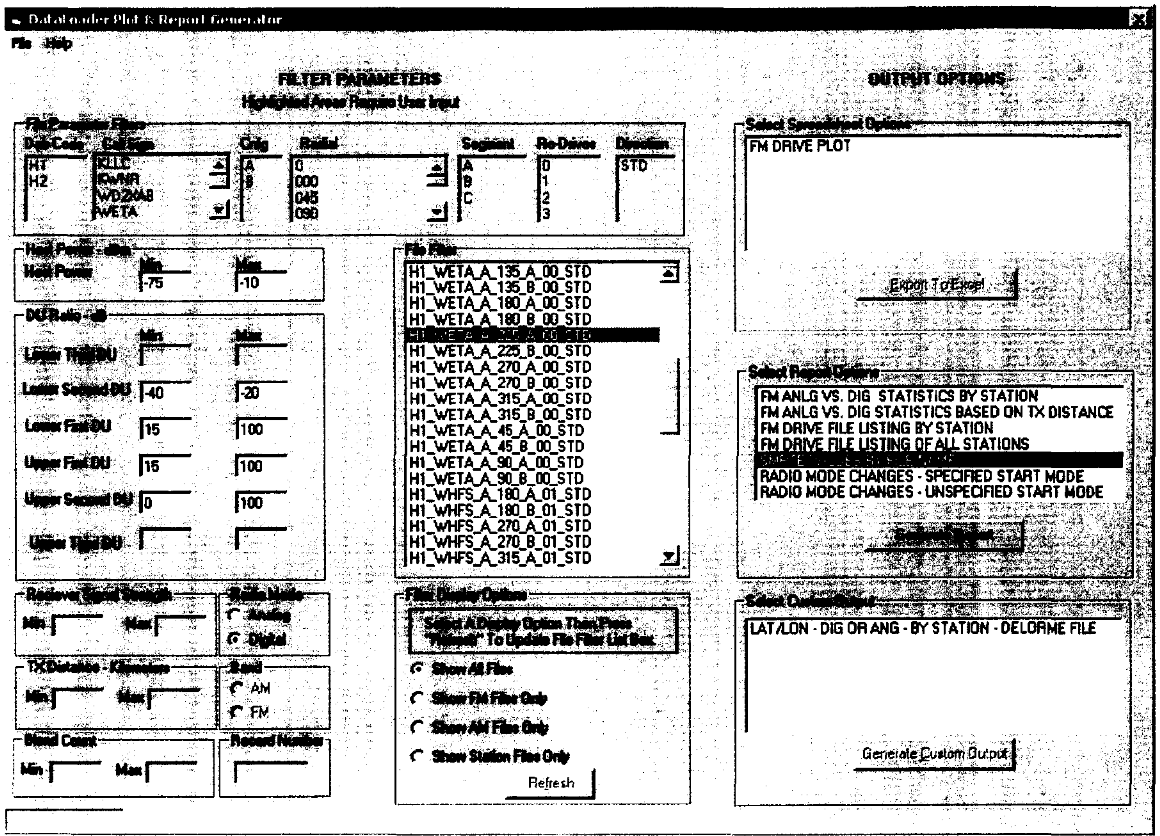

Figure 1 - *DataLoader* Plot & Report Generator GUI

During the process of building the field test database, *DataLoader* performs several operations on the field test spectrum analyzer data. For each frame of FM-band spectral data that meets predetermined span and resolution bandwidth criteria, *DataLoader* calculates signal levels for the desired channel and its upper and lower 1st and 2nd adjacents. *DataLoader* places these values in each record of the database, along with corresponding GPS, timecode and digital receiver performance figures.

iBiquity's *FM Field Test Procedures & Notes* specifies an optimal spectrum analyzer configuration for FM field tests. This configuration allows for complete power measurement sweeps in less than 200 milliseconds that cover the desired channel along with its upper and lower 1st, 2nd, 3rd and 4th adjacent channels. The specified resolution bandwidth of 30 kHz permits this relatively fast sweep time, but has sufficient selectivity to resolve adjacent FM channels and provide some secondary spectral detail. Using the sweep parameters and resolution bandwidth, *DataLoader* integrates the RF power within ±50 kHz of the desired, 1st and 2nd adjacent channels. Tests at iBiquity have shown this power measurement span to be a good compromise between accurate on-channel power measurement and adjacent-channel power isolation.

Both *DataLoader* and *DataView* played significant roles in the identification of field test audio samples for subjective evaluation. In particular, these tools located and verified signal strengths, desired-to-undesired ratios and digital radio modes in the search for audio cuts to represent various adjacent channel interference conditions.

In the first step of a D/U search *DataLoader*'s **SMPTE VALUES BY FILE NAME** report option was employed by entering filter selections for a particular drive file (radial or loop), radio mode and the search ranges for desired signal strength and all 1st and 2nd D/U ratios. From this input, *DataLoader* searched the database and generated a summary report of the query criteria followed by a listing of results. The returned results were record numbers and SMPTE timecodes corresponding to the field test data records that meet the search criteria. Figure 2 shows a sample report. After reports were generated for all stations and radials of interest, *DataView* reviewed the complete spectral data at and near the record/SMPTE locations from the report(s).

iBIQUITY DIGITAL

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SMPTE Results Based On Host Power/DU Ratios/Radio Mode

Drive Data Filename: H1_WHFS_A_45_A_01_STD

Search Criteria Used:	Radio Mode: Digital	Min Lower 1st DU: 0	Min Upper 1st DU: 15
	Min Host Power: -75	Max Lower 1st DU: 25	Max Upper 1st DU: 100
	Max Host Power: 0	Min Lower 2nd DU: 0	Min Upper 2nd DU: 0
		Max Lower 2nd DU: 100	Max Upper 2nd DU: 100

RecNum :	2	SMPTE :	10000
RecNum :	5	SMPTE :	13
RecNum :	9	SMPTE :	44
RecNum :	14	SMPTE :	121
RecNum :	15	SMPTE :	127
RecNum :	18	SMPTE :	153
RecNum :	20	SMPTE :	206
RecNum :	23	SMPTE :	230
RecNum :	24	SMPTE :	236
RecNum :	32	SMPTE :	338

Figure 2: Section of a *DataLoader* Query Report

Review of the data with *DataView* was a critical step in data selection. The signal power calculation algorithms used in *DataLoader* were accurate, but indiscriminate. Whereas, a blind search of signal level and D/U ratios using *DataLoader* will produce mathematically correct results, their usefulness depends upon the signal actually captured by the spectrum analyzer. In some cases, the spectrum analyzer may be capturing something other than the desired signals or conditions. Thus, in screening the candidate data with *DataView*, iBiquity verified that:

- The spectrum analyzer sweep data appeared to be properly captured and representing the band and signals of interest.
- The spectral energy in all power calculation bands was reasonably identified as FM broadcast signals.

Measurements that exhibit the following characteristics are removed from the data selection.

- The data were not within the spectrum analyzer's usable dynamic range. That is, the signals were either clipped or too close to the analyzer's noise floor.
- There was obvious, non-FM broadcast signal energy in the band(s) of interest
- There was evidence of significant multipath distortion and, therefore, accurate D/U ratios cannot be obtained through averaging or other means.

Data records removed from the query list were inappropriate for adjacent channel D/U studies, however, they remain part of the test database, as they may be significant in the characterization of other types of interference and channel condition studies.

Figure 3 is a screen shot of the *DataView* GUI showing the main window assigned to playback of the spectral data. The window overlaid on the spectral plot is the Average Power pop-up. The Average Power utility derives multi-band, average power measurements from the spectral data. Frequency bands, frame averaging and whether to use antenna network correction factors in the power calculations displayed can all be specified.

It is also possible to assign dynamically *DataView's* main data window to the camera or the route mapping/tracking. The latter assignment appears in Figure 4.

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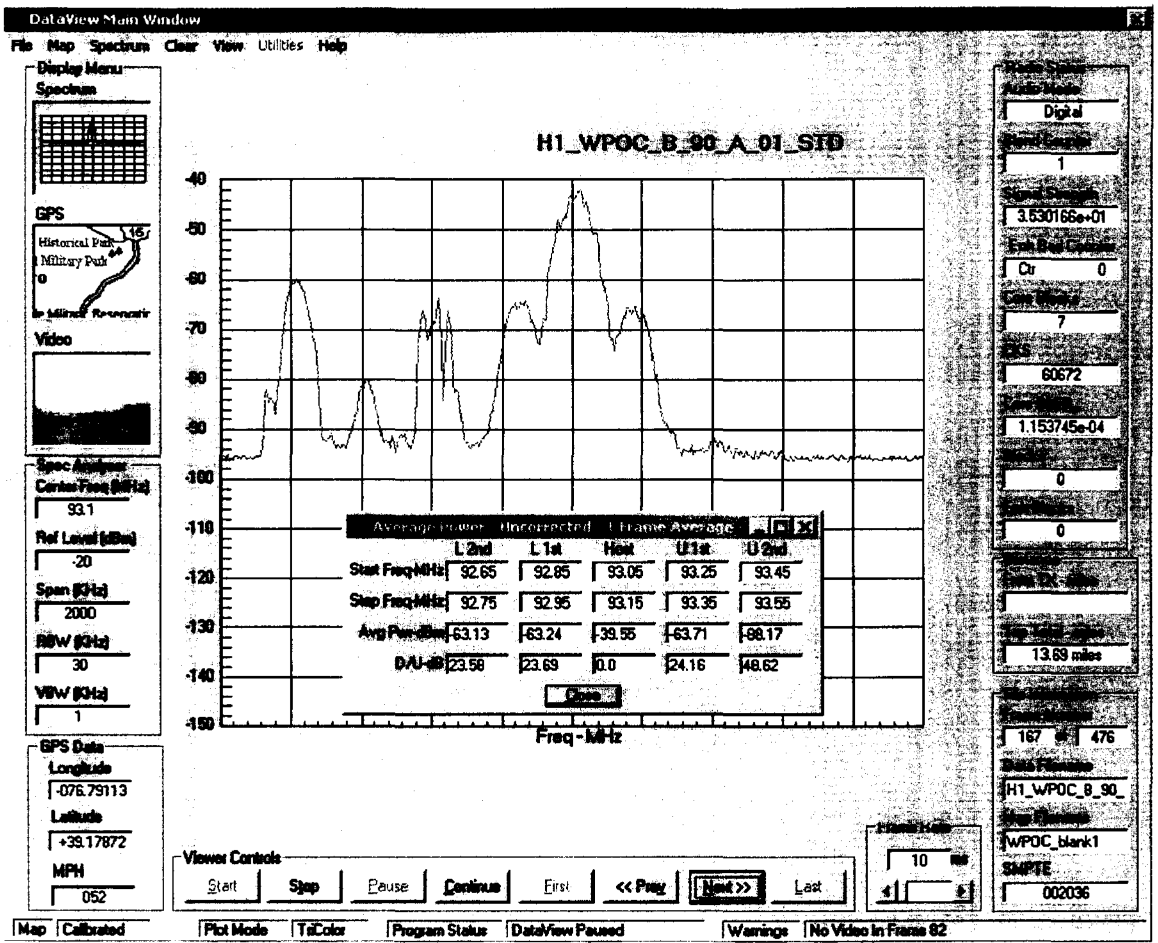

Figure 3 - *DataView* GUI with spectrum assigned to main window and average power pop-up enabled

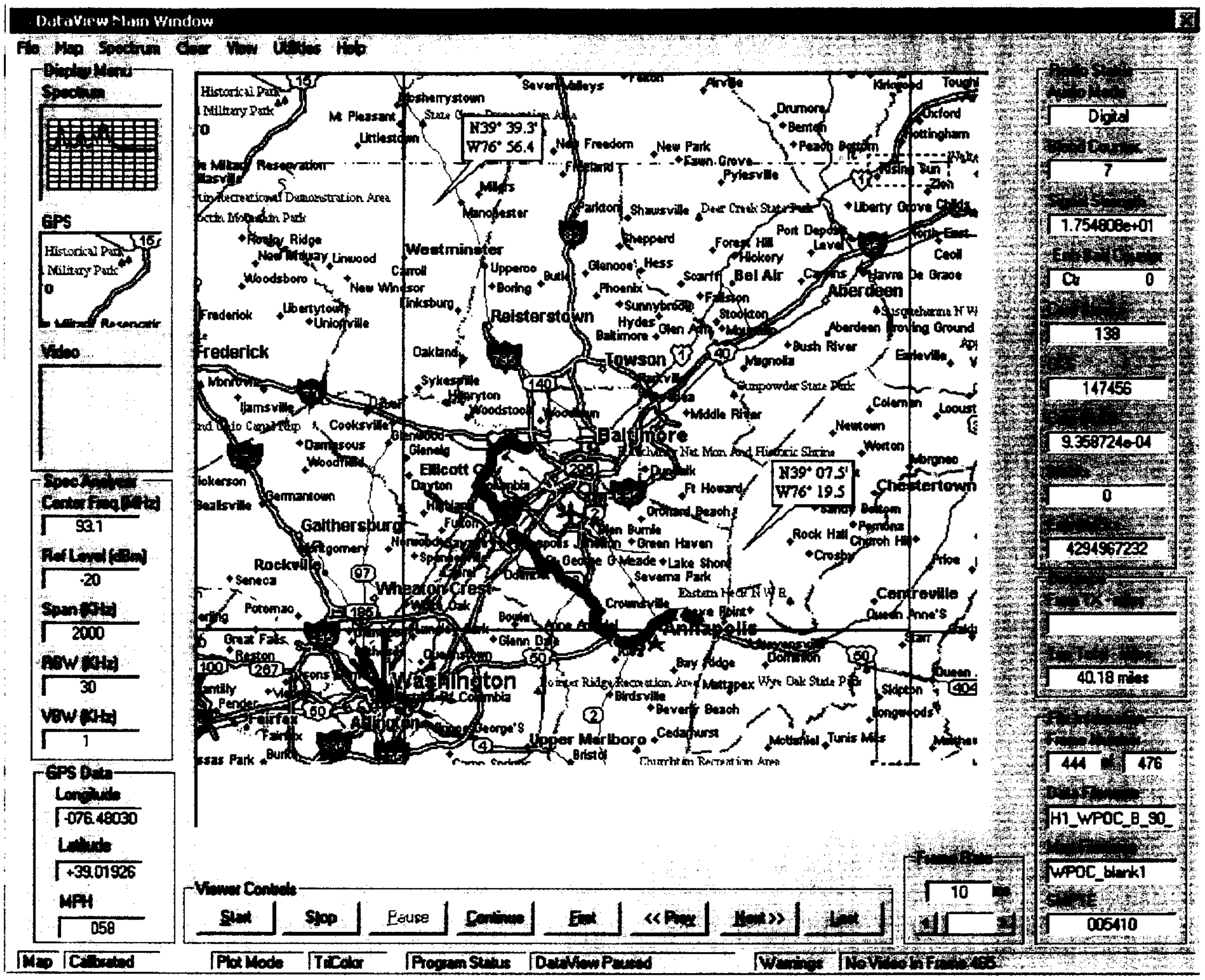

Figure 4 - *DataView* GUI with route map assigned to main window

After completing *DataLoader* queries and *DataView* reviews, the subjective testing team received the digital audio super-samples of interest. These were identified by the digital audiotapes and SMPTE timecodes that corresponded with each of the surviving query records. The subjective testing team reviewed the audio super-samples and processed these into appropriate audio samples for subjective evaluation.